A METHOD FOR THE OPTIMAL DISPOSITION OF SURPLUS AIR FORCE MOTOR VEHICLES

THESIS

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A METHOD FOR THE OPTIMAL DISPOSITION OF SURPLUS AIR FORCE MOTOR VEHICLES

THESIS

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Master of Science in Logistics Management

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Preface

The purpose of this study, sponsored by HQ TAC/LGT, was to develop an optimal disposition method for surplus motor vehicles based on a perceived need for effective resource management given DoD budget cuts and base closures. A small group of people who assisted me in my research deserve special mention.

First, I am deeply indebted to Major Paul A. Auclair and Captain John J. Borsi, Department of Operational Sciences, AFIT School of Engineering. This thesis would not have been possible without their inestimable support. As my thesis readers, they dedicated countless hours of their valuable time to my research efforts, offering guidance, instruction, direction, and correction. Among other things, they taught me the elegance of simplicity. I wish also to thank my thesis advisor, Major Robert F. McCauley, who provided advice, direction, and encouragement in the original development of this research.

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Valerie A. Tredway

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Abstract

This study developed a disposition method to enable major commands to increase the value of their vehicle fleets by optimally replacing less valuable fleet vehicles with more valuable surplus vehicles. The value of an optimal vehicle disposition method is especially significant in light of the decline in the U.S. Department of Defense (DoD) budget and base closures scheduled through fiscal year 1994. The Air Force currently spends approximately $240 million per year for vehicle replacement to maintain its motor vehicle fleet. It is advantageous, therefore, to consider replacing older vehicles in the fleet with newer surplus vehicles made available through the closures. Using a greedy algorithm approach to vehicle disposition, this research demonstrated a potential savings of almost $39,000 for the disposition of only 13 pickup trucks at a single base considered for closure. This method is more efficient than standard linear programming assignment procedures, yet is flexible enough to use in conjunction with sound judgement to support all surplus vehicle disposition decisions.

A METHOD FOR THE OPTIMAL DISPOSITION OF SURPLUS AIR FORCE MOTOR VEHICLES

I. Introduction

The purpose of this research was to incorporate vehicle replacement considerations into the Air Force surplus vehicle disposition policy. Specifically, the study developed a methodology to increase the value of a major command (MAJCOM) vehicle fleet by replacing less valuable fleet vehicles with more valuable surplus vehicles.

Deciding which vehicles should be kept or salvaged is a typical resource allocation problem. This type of problem can be solved successfully using linear programming (LP), which is a classical operations research optimization technique. However, a much simpler solution procedure applies under conditions often encountered in Air Force vehicle disposition decisions. This simpler solution procedure is the basis of the vehicle disposition methodology presented in this paper.

Chapter Overview

This chapter briefly describes the course of this research. It discusses the background, general issue, and scope of the research; defines terms used throughout the paper; and introduces the remaining chapters.

Background

> On 3 May 1988, Secretary of Defense Frank C. Carlucci chartered the Commission on Base Realignment and Closure to recommend military bases within the United States, its commonwealths, territories, and possessions for realignment and closure. (HQ 509th BMW, 1989:1)

The purpose of this action was to achieve savings in the defense budget without impairing the performance of assigned military missions. Within the Air Force, Pease AFB, New Hampshire was closed in fiscal year (FY) 1991 (Department of the Air Force, 1990a). Five more bases are time-phased for closure through FY 1994 (Department of the Air Force, 1990a). As of April 1991, 14 other Air Force installations were recommended for closure (Bird, 1991:4). Each base closure will result in surplus facilities and equipment, including hundreds of motor vehicles that must be reallocated or salvaged.

General Issue

Significant declines in the U.S. Defense budget, which began in FY 1991 and are projected through 1995, set in motion a number of force structure reductions in addition to base closures within the Department of Defense (DoD) (Morrocco, 1990:26). These reductions included budget and associated constraints on manpower, new equipment purchases, and operating and maintenance (O&M) dollars. The cost effective management of these resources is necessary to ease the transition to a smaller and more efficient military force.

In terms of motor vehicles alone, the Air Force spends approximately $240 million per year for vehicle replacement to maintain a fleet numbering approximately 128,500 units (3760 TTG, 1989:F12; Holley, 1991). While funding for vehicle replacements is decreasing, replacement-eligible vehicles represent 28 percent of the Air Force fleet; a proportion that continues to grow (Jung, 1990:7). It may, then, be advantageous to the Air Force to consider substituting the least valuable vehicles in the fleet with surplus vehicles of greater value and, presumably, longer life. With the base closure activities generating many surplus vehicles, there is an obvious opportunity to pursue significant monetary savings through judicious vehicle substitutions.

Specific Research Question

What methodology should an Air Force major command staff use to determine the disposition of surplus motor vehicles, given budgetary constraints?

Research Objectives

Three objectives guide this research:

1. Outline the current Air Force vehicle disposition policy in practice.

2. Propose a decision tool for use by a MAJCOM staff in the disposition of surplus vehicles.

3. Demonstrate the use of a structured approach to vehicle disposition.

The current method for distributing surplus Air Force vehicles is summarized below. The second and third objectives will be addressed in subsequent chapters.

Current Method

General Procedure. Chapter 17 of Air Force Manual (AFM) 67-1, Volume IV, Part One, Distribution/Redistribution, states, "Major commands will redistribute [surplus vehicles] within command to fill authorized shortages" (Department of the Air Force, 1990c:1). In addition, in accordance with AFM 77-310, Volume I, Acquisition, Management and Use of Motor Vehicles, the vehicles may be used to replace older vehicles which are determined eligible for disposal or salvage as outlined in Air Force Technical Order (AFTO) 00-25-249 (Department of the Air Force, 1991:36). AFTO 00-25-249 outlines the specific conditions necessary for vehicle replacement in reference to mileage, age, and condition of the vehicle. At this point, remaining command excesses are identified for redistribution through the registered equipment management system (REMS) to the vehicle manager at the Warner Robins Air Logistics Center (WRALC). The vehicle manager maintains Air Force-wide visibility of vehicle authorizations, shortages, and replacement eligibility.

Base Closure. In accordance with AFM 67-1, Volume II, Part Two, Base Closures, when a MAJCOM is notified of a base closure, it must determine the status of local agreements for federal aid and prepare a phasedown plan of operation. The objective of the plan is to:

> achieve a smooth, orderly closeout while the variety and number of supplies are gradually reduced. The rate of supply reduction is determined by resources and the closeout date. Phasedown actions will require careful attention...by appointed personnel. (Department of the Air Force, 1990b:61)

When specific guidance for the disposition of the assets is not available through a Headquarters Air Force or owning MAJCOM phasedown plan, program action document (PAD), or other special directive, the bases will follow the guidance of the MAJCOM (Department of the Air Force, 1990b:65).

Scope and Limitations

This thesis was sponsored by the Headquarters Tactical Air Command Transportation Directorate (HQ TAC/LGT). The aim of the research was to develop a practical method for the disposition of surplus Air Force motor vehicles.

Since it is not possible to accurately predict when surplus vehicles will be available for shipment due to mission requirements, mechanical failures, or other unforeseen circumstances, shipping costs were assumed based on a single vehicle per shipment. The impact of multiple vehicle shipments is discussed in Chapter IV. However, methodological consideration of multiple shipments is beyond the scope of this study.

The preprocessing of vehicles was assumed outside the realm of this model. In other words, vehicles were assumed to be designated as eligible for salvage or needed to fill open authorizations prior to employment of the methodology. In addition, programmed vehicle buys and due-in listings were not considered.

Definitions

Given an understanding of Air Force current procedures for distributing surplus vehicles, a series of definitions was developed to guide the research.

Fleet Vehicle. A military motor vehicle currently authorized and assigned to an active Air Force CONUS installation.

OTRA. An acronym for One-Time Repair Allowance. The OTRA is used in this thesis to represent the value measure of an Air Force motor vehicle. No source document exists which assesses the validity of the OTRA as a value measure (Hill, 1991; Holley, 1991). However, in accordance with AFTO 00-25-249, it is the accepted method by which the Air Force determines how much can be spent at any one time to repair a vehicle, based on vehicle age and mileage (AFTO 00-25-249, 1990:2-1). A more detailed discussion of the OTRA is in the Appendix.

Shipping Cost. The estimated cost to the Air Force of transporting a surplus vehicle from origin to destination via commercial motor carrier. Transportation generally is contracted by an Air Force Traffic Management Office (TMO) through the U.S. Army's Military Traffic Management Command (MTMC) (Tucker, 1991).

Surplus Vehicle. A military motor vehicle designated as excess to a current Air Force vehicle authorization due to some determining factor such as base closure.

Vehicle Disposition. Refers to the process by which a vehicle is redistributed to fill an open authorization, used to replace a fleet vehicle, or identified to the vehicle manager at WRALC for salvage or transfer (Department of the Air Force, 1990c:1; Department of the Air Force, 1991:36).

Summary

This chapter discussed the current and projected decreases in the DoD budget, and some subsequent effects of these decreases on the Air Force. The recently scheduled base closures will result in a large number of surplus vehicles which can be reallocated in such a way that the overall age and mileage of the Air Force vehicle fleet improves at minimal cost. This is an important opportunity in light of current and projected resource constraints.

An understanding of concepts necessary to the development of decision criteria is provided in Chapter II by way of a literature review of linear programming and the assignment model. Chapter III outlines the development of the solution technique used to address the research problem. The demonstration and analysis of the technique is the subject of Chapter IV. Finally, Chapter V summarizes the research and presents recommendations for further research.

II. Literature Review

As stated in Chapter I, the vehicle disposition problem is a typical resource allocation problem. This problem can be solved optimally using linear programming (LP). John Hargreaves, author of an article entitled "Resource Allocation: Optimisation for Tomorrow's Demand," concurs:

> In solving resource allocation problems, the power of optimisation techniques cannot be matched by...alternatives. The use of large-scale optimisation models based on mathematical programming techniques has proven to be a powerful, effective technique for resource allocation. (Hargreaves, 1989:24)

Chapter Overview

This chapter establishes the framework for developing the solution technique in Chapter III with a discussion of LP. Following this discussion, a special case of LP is introduced -- the assignment model. This model is a network-oriented approach to resource allocation which involves some type of distribution or allocation (Trueman, 1977:322). Finally, use of an assignment problem solution technique, the Hungarian method, will illustrate the procedure for a typical assignment problem scenario.

The discussion here is not intended to prepare the unindoctrinated reader to solve LP problems. Rather, its purpose is to review a method of problem solving concerned with the "determination of the best allocation of scarce resources" (Cook and Russell, 1989:32). For a more complete presentation of the subject, the reader is encouraged to refer to any management science text. A recommended source is Cook and Russell's Introduction to Management Science (see Bibliography).

Linear Programming

LP is a component of the field of mathematical programming, which deals with modeling and solution procedures designed to "maximize the extent to which the goals and objectives of the decision maker are realized" (Cook and Russell, 1989:32). By meeting special linearity conditions, a mathematical model becomes an LP model, which uses mathematical techniques to set up and solve a system of linear equations.

From a practical view, the use of LP can provide an optimal solution to the problem of maximizing or minimizing some goal within the bounds of cost, demand, and/or supply (Pinney and McWilliams, 1987:92-93). The goal of an LP problem is known as the objective, or linear, function and the bounds are described by linear constraints (Pinney and McWilliams, 1987:92). Examples of problems suitable for formulation as linear programs include blending, product mix determination, physical distribution, production scheduling and inventory planning, and purchasing (Cook and Russell, 1989:34-35).

The linear objective function and constraints form the LP model (Cook and Russell, 1989:35-6). The canonical form of the LP model with n independent variables and m constraints, taken from Cook and Russell, is

Maximize

$$c_1x_1+c_2x_2+\ldots+c_nx_n \tag{1}$$

subject to restrictions

$$a_{11}x_1+a_{12}x_2+\ldots+a_1nx_n\leq b_1 \tag{2}$$

$$a_{21}x_1+a_{22}x_2+\ldots+a_2nx_n\leq b_2$$

$$\vdots$$

$$a_{m1}x_1+a_{m2}x_2+\ldots+a_{mn}x_n\leq b_m$$

and

$$x_1\geq 0, x_2\geq 0, \ldots, x_n\geq 0 \tag{3}$$

where

c_j, a_{ij}, b_i = parameters, or input data
(for $i = 1,2,\ldots,m; j = 1,2,\ldots,n$)

x_j = decision variables
(for $j = 1,2,\ldots,n$)

Eq (1), the objective function, is a mathematical expression reflecting the desire to maximize a goal. The restrictions represented by Eq (2) are the constraints, typically expressed as limitations on available resources or demand (Cook and Russell, 1989:36). Eq (3) establishes nonnegativity conditions, limiting the variables to positive numbers or zeroes.

Some LP models do not fit the exact canonical form (Cook and Russell, 1989:36). Variations include an objective function that is to be minimized and constraint equalities, rather than inequalities.

The basic technique most often used for solving LP problems is the simplex algorithm (Pinney and McWilliams, 1987:123). "An algorithm is an iterative procedure with specific computational rules that solves a problem in a finite number of steps" (Cook and Russell, 1989:101). It is similar to the algebraic solving of a system of linear constraints for all possible intersection points (Cook and Russell, 1989:101; Brown and ReVelle, 1978:85). These intersection points are then systematically introduced into the objective function until an optimum solution is either obtained or found not to exist (Brown and ReVelle, 1978:85). There can be multiple optimum solutions, which are referred to as alternate optima (Cook and Russell, 1989:135).

The assignment model is a special LP model that readily applies itself to this problem structure (Cook and Russell, 1989:198). The nature of the assignment model, which is detailed in the next section, makes it a suitable solution procedure for the vehicle disposition problem.

Assignment Model

The assignment model is a member of a larger group of network models (Cook and Russell. 1989:199). Network models take advantage of a special mathematical structure that can yield cost savings in terms of computation over the general LP simplex algorithm. The solution algorithm is aptly referred to as a special-purpose algorithm (Cook and Russell, 1989:199). The advantages of special-purpose algorithms for the assignment problem follow:

> 1. Computation time is generally 100 to 150 times faster than the general simplex method.
>
> 2. Significantly less computer memory is required, thus permitting even larger problems to be solved.
>
> 3. ...assignment problems that have integer (whole-number) data yield integer solutions... (Cook and Russell, 1989:199)

The assignment model is concerned with the optimal one-to-one assignment of resources such as jobs to machines, or workers to tasks (Cook and Russell, 1989:219). Given the cost of making each assignment, the goal is to minimize the total cost of all assignments (Trueman, 1977:315). The problem can be formulated mathematically (Trueman, 1977:315):

Let

c_{ij} = cost of assigning worker i to task j

$$x_{ij} = \begin{cases} 1 \text{ if worker } i \text{ is assigned to task } j \\ 0 \text{ otherwise} \end{cases}$$

$$\sum_{i=1}^{m}\sum_{j=1}^{m} x_{ij}c_{ij} \tag{4}$$

subject to

$$\sum_{i=1}^{m} x_{ij}=1, \qquad j=1,2,\ldots,m \tag{5}$$

$$\sum_{j=1}^{m} x_{ij}=1, \qquad i=1,2,\ldots,m \tag{6}$$

Eq (4) is the objective function, which is to minimize the total cost of assigning the workers to the tasks. The constraints in Eqs (5) and (6) restrict the assignment of each worker to one task, and each task to one worker, respectively.

The assignment problem can be solved efficiently using an algorithm known as the Hungarian method, named in honor of D. König, a Hungarian mathematician who proved a theorem required for its development (Cook and Russell, 1989:248).

Hungarian Method. The Hungarian method is performed on a matrix of assignment costs, as indicated by Figure 1. The origins, or sources, are each assigned a row; destinations and corresponding demands are each assigned columns. Each cell represents a different assignment of a source to a destination (Heinze, 1978:238). For x_{ij} and c_{ij}, i designates the row (source), and j represents the column (destination) (Pinney and McWilliams, 1987:210).

Destinations

	D_1	D_2	D_3
S_1	c_{ij}	c_{ij}	c_{ij}
S_2	c_{ij}	c_{ij}	c_{ij}
S_3	c_{ij}	c_{ij}	c_{ij}

Figure 1. Assignment Problem Matrix (adapted from Pinney and McWilliams, 1987:211)

An underlying principle of the Hungarian method is the fact that a constant can be added or subtracted from any row or column of the cost matrix without changing the optimal assignments of the problem (Cook and Russell, 1989:248).

For any assignment cost matrix array of size $m*m$ (by including dummy rows and/or columns as necessary), the Hungarian method can be summarized as follows:

Step 1. Subtract the minimum element in each row from all elements in that row. Subtract the minimum element in each column from all elements in that column. (Either row or column subtractions can be performed first.)

Step 2. Cover all zeroes by the minimum possible number of lines drawn through rows and/or columns. If the number of covering lines is less than m, go to Step 3. If the number of covering lines is equal to m, the solution is optimal. Go to Step 4.

Step 3. Find the minimum element value, V, not covered by a line. Subtract V from each element not covered by a line and add V to every element at the intersection of two lines. Go to Step 2.

Step 4. Determine the optimal assignments. A single zero in a row or column immediately identifies an optimal assignment. By crossing off rows and columns for which assignments have been determined, the remaining assignments will be found by a process of elimination. There may be more than one optimal solution. (Trueman, 1977:319).

An example assignment problem using the Hungarian method is described below:

> A trucking concern has five trailers awaiting pickup at different locations in a city. In a nearby city, it has five tractors, each one capable of handling any of the trailers. Given the distance, in miles, between each tractor and each trailer, as shown in [Table 1], what is the selection of tractor-trailer allocations which will minimize the total distance traveled to pick up the trailers? (Trueman, 1977:316)

TABLE 1

ASSIGNMENT PROBLEM DATA

		Trailer				
		1	2	3	4	5
Tractor	A	18	16	23	19	14
	B	25	21	19	23	17
	C	16	17	20	18	22
	D	19	17	25	22	21
	E	14	13	17	17	16

The first step of the Hungarian method is to find the minimum element in each row and subtract it from each of the remaining elements in that row, as in Table 2 (Trueman, 1977:316). On a comparative basis, nothing in the problem has changed. In other words, since each tractor must be

TABLE 2

ASSIGNMENT PROBLEM -- FIRST REDUCTION

	1	2	3	4	5	Minimum
A	4	2	9	5	0	14
B	8	4	2	6	0	17
C	0	1	4	2	6	16
D	2	0	8	5	4	17
E	1	0	4	4	3	13
						77

assigned to one of the five trailers, this step has simply reduced the distance by some amount for each assignment. The optimal assignment for this partially solved problem will be the same as for the original distance array (Trueman, 1977:316). The total distance has decreased, however, by 77 units (miles), which is the sum of the row element reductions.

The next step is to subtract the minimum element in each column from the remaining elements in that column. Table 3 illustrates what is called a fully reduced array, in which every row and column have at least one zero (Trueman, 1977:316).

At this point, an attempt is made to make a set of assignments. If all of the tractors can be assigned to all of the trailers using only the zero distance values, then the assignment is optimal, with a total distance equal to

TABLE 3

ASSIGNMENT PROBLEM -- SECOND REDUCTION

	1	2	3	4	5	
A	4	2	7	3	0	
B	8	4	0	4	0	
C	0	1	2	0	6	
D	2	0	6	3	4	
E	1	0	2	2	3	
Minimum	0	0	2	2	0	4 (total)

the sum of row and column element reductions (Trueman, 1977:316).

Examination of the tableau in Table 3 should reveal that optimal assignments using only zero distance elements cannot be made, since the only zero values for rows D and E are both in the second column. This cannot be optimal since only one tractor can be assigned to one trailer. Therefore, another iteration is necessary to create more zero elements. The next step will involve adding and subtracting a constant from certain rows and columns.

First cover all the zeroes in the table by the minimum number of horizontal and vertical lines that can be drawn across the rows and columns, as shown in Table 4 (Trueman, 1977:317). This procedure has a dual purpose. If a minimum number of m lines (in this case, five) is needed to cover

TABLE 4

COVERING THE ZEROES IN THE ASSIGNMENT TABLEAU

	1	2	3	4	5
A	4	2	7	3	0
B	8	4	0	4	0
C	0	1	2	0	5
D	2	0	6	3	4
E	1*	0	2	2	3

*V = 1 (Cell E, 1)

all zeroes, there is a set of independent zeroes (Trueman, 1977:318). An optimal solution can then be determined. The solution may be unique, or there may be multiple optimal solutions. If fewer than *m* can be drawn, the pattern of lines will indicate what the next step should be (Trueman, 1977:318).

Since the zeroes in Table 4 can be covered by four lines, this is not an optimal solution. The next step is to locate the smallest element value *V* that is not crossed out by a line. This number is subtracted from every uncovered element in the matrix, and must also be added to the cell values located underneath the intersection of any two lines (Trueman, 1977:318). Again, lines are drawn to cover all of the zeroes. The results are shown in Table 5 (Trueman, 1977:317).

TABLE 5

SECOND COVERING OF ZEROES IN ASSIGNMENT TABLEAU

	1	2	3	4	5
A	3	2	7	2	0
B	7	4	0	3	0
C	0	2	3	0	7
D	1	0	6	2	4
E	0	0	2	1	3

*V = 1 (Cell E, 1)

This time it takes five lines, which signals five independent zeroes (Trueman, 1977:319). The optimal solution is found by the process of elimination in Step 4 of the algorithm. These assignments are listed in Table 6 (Trueman, 1977:319).

TABLE 6

ASSIGNMENT PROBLEM SOLUTION SET

Tractor	Trailer	Distance (mi)
A	5	14
B	3	19
C	4	18
D	2	17
E	1	14
		82

Numerous aspects of the Hungarian method solution procedure are worth noting. First, the coverage of zeroes in a table can be accomplished by a number of different combinations of horizontal and vertical lines. Second, throughout the solution procedure, the order in which the assignments are made is nonunique (Trueman, 1977:319). Also, if the number of rows and number of columns are unequal, a dummy row or column is added as required, with the cell value(s) set to zero (Trueman, 1977:319). An optimal solution could include a dummy assignment if the zero value is better than another assignment for the problem under consideration.

In addition, the procedure outlined above, which addresses a minimization problem, can easily be converted into a maximization problem by finding the largest elements, instead of the smallest elements, in Steps 1 and 3. Finally, multiple optimal solutions are indicated by a large number of zeroes in the final solution set. When more than one set of optimal assignments exists, the choice of a particular combination can then focus on other criteria, such as "personal preferences, time considerations, and organizational idiosyncracies" (Pinney and McWilliams, 1987:208).

Summary

This chapter provided only a cursory discussion of linear programming, or LP. LP, a subgroup of mathematical programming, is an ideal tool for making decisions that can be expressed in the form of linear equations and constraints. In fact, "(LP) is the most widely applied quantitative decision-making tool in business and industry" (Pinney and McWilliams, 1987:91). The assignment problem is a special LP problem which can be solved very efficiently. A common solution technique is the Hungarian method.

This problem type fits the nature of the vehicle disposition problem, which entails assigning one surplus vehicle to substitute for one fleet vehicle. Disposition decisions should be made in a manner which maximizes the overall value of a vehicle fleet. This value is measured in terms of an increase in the overall one-time repair allowance after estimated shipping costs are considered. This approach is developed in Chapter III.

III. Development of Solution Technique

The importance of achieving good solutions for surplus vehicle disposition is emphasized by the constrained financial resources forecasted through fiscal year (FY) 1995, and by the current pace of change and realignment in the Air Force. This chapter addresses solution methodologies to the surplus vehicle disposition problem based on linear programming (LP) and a greedy algorithm.

The first section presents the definition of the vehicle disposition problem. This section is followed by a discussion of a surplus vehicle disposition plan based on LP. The third section describes a simpler, greedy algorithm, that under certain conditions, also provides optimal solutions. The final section provides proof of the optimality of the greedy algorithm.

The Surplus Vehicle Disposition Problem

The goal of optimal surplus vehicle disposition is to maximize the overall value of the remaining vehicle fleet. Given a set number of vehicles must be retired from the fleet, a proper vehicle disposition decision will identify the least valued set of vehicles for salvage. Such a decision implicitly maximizes the value of the set of vehicles remaining in the fleet.

As explained in Chapter I, the one-time repair allowance (OTRA) is used to represent the inherent value of each vehicle. The Appendix provides additional detail on the OTRA and how it is calculated.

Vehicle disposition decisions may stipulate that a surplus vehicle substitute for another vehicle in the fleet rather than go to salvage. Consequently, the cost of shipping a surplus vehicle to another location must be considered in determining the remaining fleet value.

Shipping costs can only be estimated for several reasons. The Air Force hires many carriers, so costs typically vary between transportation companies and over time. Shipping costs also differ by load size and destination. In addition, vehicles designated as surplus due to a base closure might be shipped in multiple quantities at a discounted price per vehicle.

The disposition decision, therefore, is based on three parameters. The OTRA of the surplus vehicles and the OTRA of fleet vehicles constitute two of the parameters. The third is the cost of shipping a surplus vehicle from its origin to each of a set of possible destinations.

Given OTRAs and estimated shipping costs, the question faced by the decision maker is how to best assign surplus vehicles to replace similar vehicles in the fleet or be identified to the vehicle manager at Warner Robins (WRALC) for disposition. Since disposal is the normal course of action when vehicle replacements are not considered, it is referred to as the "do nothing" option. The cost matrix components of the problem are represented by

S_i,	for $i = 1,\ldots,m+n$	sources (surplus vehicles or dummy variables)
F_j,	for $j = 1,\ldots,n+m$	destinations (fleet vehicles or do nothing option)
O_i,	for $i = 1,\ldots,m$	the OTRA of a surplus vehicle (S_i)
O_j,	for $j = 1,\ldots,n$	the OTRA of a fleet vehicle (F_j)
T_{ij},	for all i and j	estimated shipping cost for a particular surplus vehicle S_i to replace a fleet vehicle F_j

In general, the decision maker must make disposition decisions based on a comparison of the O_i, O_j, and T_{ij} components for every possible combination of excess and remaining fleet vehicles. Mathematically, the potential benefit from each transaction, c_{ij}, equals

$$c_{ij} = \text{Surplus vehicle OTRA} \text{ minus } \text{Fleet vehicle OTRA} \text{ minus } \text{Estimated shipping cost}$$

$$= O_i - O_j - T_{ij}$$

Each possible substitution has its own positive or negative benefit. Benefit refers to the change in the cumulative OTRA value of the vehicle fleet caused by the substitution of a surplus vehicle for a fleet vehicle. Positive values of c_{ij} suggest a potential advantage in replacing a remaining vehicle with an excess vehicle, while a negative value implies a trade is ill-advised. If no trade occurs, then the value of c_{ij} is zero, since the overall value of the remaining fleet is unaffected and no transportation costs are incurred. Figure 2 shows the cost matrix for the vehicle disposition problem.

	REMAINING FLEET VEHICLES (n)	DO NOTHING (m)
SURPLUS VEHICLES (m)	Substitute surplus vehicle for fleet $c_{ij} = O_i - O_j - T_{ij}$ for $i=1,\ldots,m;$ $j=1,\ldots,n$	No trade $c_{ij} = 0$ for $i=1,\ldots,m;$ $j=1,\ldots,n+m$
DO NOTHING (m)	No trade $c_{ij} = 0$ for $i=1,\ldots,m+n;$ $j=1,\ldots,n$	No trade $c_{ij} = 0$ for $i=1,\ldots,m+n;$ $j=1,\ldots,n+m$

Figure 2. Vehicle Disposition Cost Matrix

The general LP formulation is applicable regardless of the number of sources of surplus vehicles. The optimality of the greedy algorithm discussed later in the chapter, however, requires all surplus vehicles to originate from either a single source or multiple sources having identical shipping costs.

Linear Programming Solution Approach

Vehicle disposition as defined here is an LP assignment problem because it is concerned with one-on-one assignments. That is, the decision must substitute one surplus vehicle for one remaining fleet vehicle or do nothing (no trade). The model parameters have already been defined:

O_i = OTRA of a surplus vehicle i ($i=1,2,\ldots,m$)

O_j = OTRA of a fleet vehicle j ($j=1,2,\ldots,n$)

T_{ij} = Estimated shipping cost to substitute vehicle i for vehicle j ($i=1,2,\ldots,m; j=1,2,\ldots,n$)

c_{ij} = Net benefit of an assignment of vehicle i to vehicle j ($i=1,2,\ldots,m; j=1,2,\ldots,n$)

The decision variable is x_{ij}, which identifies whether or not surplus vehicle i substitutes for fleet vehicle j. Let

$$x_{ij} = \begin{cases} 1 & \text{if vehicle } i \text{ is assigned to vehicle } j \text{ or to a do nothing option } j \\ 0 & \text{otherwise.} \end{cases}$$

The optimal assignment can be found by solving the LP formulation:

Maximize

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \qquad (7)$$

subject to

$$0 \le x_{ij} \le 1 \qquad (i=1,2,\ldots,m+n;\ j=1,2,\ldots,n+m) \tag{8}$$

$$\sum_{i=1}^{m+n} x_{ij}=1 \qquad (j=1,2,\ldots,n+m) \tag{9}$$

$$\sum_{j=1}^{n+m} x_{ij}=1 \qquad (i=1,2,\ldots,m+n) \tag{10}$$

Eq (7) represents the maximization of the benefits from excnanging vehicles. Eq (8) says the decision variables x_{ij} are restricted between the range of zero and one. Although fractional values of the decision variables are typical of LP solutions, such is not the case with the assignment problem. The assignment problem's optimal solution always contains whole-number decision variables. Eq (9) indicates each surplus vehicle is to be assigned to exactly one fleet vehicle or to a do nothing (no trade) option. Eq (10) indicates each fleet vehicle is to be substituted by exactly one surplus vehicle or assigned to a do nothing (no trade) option.

This problem can be solved optimally using any number of standard LP optimization techniques. However, larger problems represent more cumbersome and time-consuming applications. The size of the problem can be important when considering surplus vehicles. In a base closure, decision makers might have to determine whether to substitute any of

100 surplus sedans into a pool of 1,500 remaining fleet vehicles. This would involve the computation and evaluation of $(100+1,500)^2$, or 2,560,000 possible transactions, when taking all of the do nothing options into account. Although such problems do not necessarily exceed the capability of modern computer algorithms, they may tax the resources available to the vehicle management teams. The need for a practical solution to vehicle disposition motivated the development of the greedy algorithm as shown in the following section.

Greedy Algorithm Methodology

Definition. For a special case of the vehicle disposition problem, a much simpler method can be used. This method, a greedy algorithm, works when surplus vehicles are derived from a single origin or from multiple locations having identical shipping costs. A "greedy" algorithm is so named because at each step of its iterative process, the best current solution is selected and never reconsidered later (Mason, 1990:418). For the vehicle disposition problem, the objective is to achieve the greatest possible benefit from a series of surplus vehicle to fleet vehicle transactions. This algorithm for determining which surplus vehicles to retain and which fleet vehicles to salvage is described below.

Greedy Algorithm.

Step 1. Calculate the OTRA, O_i $(i=1,2,...,m)$, for each surplus vehicle of a specified vehicle type.

Step 2. Order the list of surplus vehicles from highest O_i (at the top of the list) to lowest.

Step 3. Find (O_j+T_{ij}) $(i=1,2,...,m; j=1,2,...,n)$, OTRA plus shipping cost, for each fleet vehicle.

Step 4. Order the list of fleet vehicles from lowest (O_j+T_{ij}) (at the top of the list) to highest.

Step 5. If the number of fleet vehicles (n) exceeds the number of surplus vehicles (m), truncate the list of fleet vehicles. As a result, each column will have m elements, thus forming sets of matched pairs.

Step 6. Index each list for order of replacement consideration, beginning at the top and labelling each pair on the lists in succession.

Step 7. Calculate the residual value of replacement for each of the indexed pairs. The residual value of replacement is $O_i-(O_j+T_{ij})$.

Step 8. Designate the matched pairs with positive residual values of replacement for substitution. Those surplus vehicles not selected for substitution then would be identified to WRALC for further disposition. Fleet vehicles not designated for substitution would remain in the fleet.

An illustration of these steps using arbitrary numbers is outlined below. The total number of surplus vehicles (m) is 9; the list of fleet vehicles (n) contains 13. The results of Steps 1 through 4 are listed in Table 7.

TABLE 7

ILLUSTRATION OF GREEDY ALGORITHM
STEPS 1, 2, 3, AND 4

Surplus Vehicles (O_i)	Fleet Vehicles (O_j+T_{ij})
5,800	200
5,400	350
4,100	500
3,700	900
2,000	1,100
1,800	1,600
1,000	2,300
750	2,800
400	3,200
	3,700
	4,700
	5,900
	6,300

In accordance with Step 5, the list of fleet vehicles is truncated. In Step 6, each list is indexed for order of replacement consideration. The residual value of replacement is calculated for each pair in Step 7. Table 8 indicates the results of these steps.

Step 8 is the final step of the greedy algorithm procedure. This step involves the selection of the matched pairs with positive residual values of replacement. Referring to Table 8, the residual values for replacement considerations 1, 2. 3, 4, 5, and 6 are positive.

TABLE 8

ILLUSTRATION OF GREEDY ALGORITHM
STEPS 5, 6, AND 7

Surplus Vehicles Replacement Consideration O_i	Fleet Vehicles Replacement Consideration (O_j+T_{ij})	Residual Value of Replacement $O_i-(O_j+T_{ij})$
1. 5,800	1. 200	1. 5,600
2. 5,400	2. 350	2. 5,050
3. 4,100	3. 500	3. 3,600
4. 3,700	4. 900	4. 2,800
5. 2,000	5. 1,100	5. 900
6. 1,800	6. 1,600	6. 200
7. 1,000	7. 2,300	7. (-1,300)
8. 750	8. 2,800	8. (-2,050)
9. 400	9. 3,200	9. (-2,800)

Therefore, these pairs would be included in the vehicle disposition plan. These transactions will result in the greatest overall increase in the value of the vehicle fleet based on OTRAs and estimated shipping costs, as proven in the next section. The three surplus vehicles not selected for substitution then would be identified to WRALC.

For each transaction, the benefit is represented by $O_i-(O_j+T_{ij})$. The total benefit of a solution is the sum of these individual benefits, which is independent of the individual matchings. Therefore, any combination of pairings between surplus and fleet vehicles within a solution set will yield the same overall increase in vehicle fleet value.

The final section shows that this greedy algorithm procedure yields an optimal solution to the vehicle disposition assignment problem.

Greedy Algorithm Proof of Optimality

This section will demonstrate that the greedy algorithm methodology discussed previously generates optimal solutions for the vehicle disposition problem. First consider the (m+n)*(n+m) assignment tableau illustrated in Figure 3, where

S_p, S_c, and S_d = surplus vehicles p, c, and d $(i=1,2,...,m+n)$

F_p, F_a, and F_b = fleet vehicles p, a, and b $(j=1,2,...,n+m)$

"+" = nonnegative c_{ij} value

"-" = negative c_{ij} value

Matrix Characteristics. The m righthand columns and the n bottom rows represent the "do nothing" option referred to in the first section (The Surplus Vehicle Disposition Problem). Recall that when a surplus vehicle does not substitute for a fleet vehicle, no positive or negative benefit is incurred. As a consequence, the c_{ij} cell values in this region are each set to zero.

The remainder of the rows and columns make up an m*n square submatrix. This matrix may be entirely negative, nonnegative, or some combination of both, depending on the actual O_i, O_j, and T_{ij} values being considered. Figure 3 illustrates a scenario in which only some of the surplus

	F_1	...	F_a	...	F_p	...	F_b	...	F_n	...	F_{n+m}
S_1	+	+	+	+	+	+	+	+	+	0	0
⋮	+	+	+	+	+	+	+	+	+	0	0
S_c	+	+	+	+	+	+	+	+	+	0	0
⋮	+	+	+	+	+	+	+	+	-	0	0
S_p	+	+	+	+	+	+	-	-	-	0	0
⋮	+	+	+	+	+	-	-	-	-	0	0
S_d	+	+	+	+	-	-	-	-	-	0	0
⋮	+	+	+	+	-	-	-	-	-	0	0
S_m	+	+	+	+	-	-	-	-	-	0	0
⋮	0	0	0	0	0	0	0	0	0	0	0
S_{m+n}	0	0	0	0	0	0	0	0	0	0	0

Figure 3. (m+n)*(n+m) Assignment Tableau

vehicle O_i values are greater than the fleet vehicle (O_j+T_{ij}) values. For instance, for vehicles S_p and F_b, O_i is less than (O_j+T_{ij}), resulting in $c_{ij}<0$.

The order in which the vehicles are listed in the tableau is completely arbitrary. However, this discussion will introduce a particular ordering of the S_i and F_j values along the rows and columns of the m*n matrix to establish a pattern of negative cell values within the tableau. The surplus vehicles are assigned to the rows from top to bottom by decreasing O_i value. Conversely, the fleet vehicles are assigned to the columns from left to right by increasing (O_j+T_{ij}) value. The largest positive c_{ij} benefit, if any, will be in the uppermost left corner of the m*n matrix. The smallest, or greatest negative, benefit will likewise be in the bottom right corner of the matrix. For any negative cell value, there must be negative values in all cells to the right of that cell, through F_n, and below that cell, through S_m.

For example, consider $c_{pb} = O_p-O_b-T_{pb} < 0$. Since all of the rows below S_p contain S_i with smaller values of O_i, it follows that all of the cells below the S_pF_b cell must also contain negative c_{ip} values. Likewise, since all of the columns to the right of F_b contain F_j with greater values of (O_j+T_{ij}), it follows that all of the cells to the right of the S_pF_b cell must contain negative values. This results in a stairstep pattern of negative cell values (when present) within the matrix. The pattern is illustrated by the heavy dashed line in Figure 3.

Within the m*n matrix is another region of interest: the largest square submatrix of all nonnegative values. For

Figure 3, this largest square is represented by the p*p matrix (S_p*F_b) bordered by the double lines.

Solution Characteristics. Assume a given solution to the assignment problem contains a decision variable with a negative benefit. In Figure 3, x_{db} represents such a decision variable as $c_{db} = O_d - O_b - T_{bd} < 0$. The effect of including x_{db} in the solution is to reduce the value of the objective function. As a result, the optimal vehicle assignment would include a transaction that is not beneficial. Since the assignment tableau includes a do nothing assignment for each surplus vehicles, a do nothing decision variable with a benefit of zero could always replace a decision variable with a negative benefit. Therefore, a transaction with a negative return cannot be in an optimal solution.

A nonnegative cell value not located within the p*p matrix depicted in Figure 3 falls in the stairstep region of the assignment tableau. Optimal solutions exist where none of the decision variables associated with this stairstep region are positive. To demonstrate this point, assume a feasible solution exists where $c_{ij} \geq 0$ for each $x_{ij}=1$. Assume further that at least one positive decision variable x_{kh} is associated with this stairstep region. Without loss of generality, let h>p.

In a feasible assignment, every row i has only one $x_{ij}=1$, and every column j has only one $x_{ij}=1$. If a column z in the p*p submatrix is assigned to a do nothing option this assignment can be exchanged with the assignment for x_{kh} without decreasing the objective function value (since $c_{sh} \geq c_{kh}$). Otherwise, referring to Figure 4, there exists a row r with $x_{rh}=0$ and $c_{rh}<0$. For this row there is some $x_{rc}=1$

	F_1	...	F_c	...	F_p	...	F_h	...	F_n
S_1									
. . .									
S_k			$x_{kc}=0$				$x_{kh}=1$		
. . .									
S_p									
. . .									
S_r			$x_{rc}=1$				$x_{rh}=0$		
. . .									
S_m									

Figure 4. $m*n$ Assignment Tableau

with c_{rc} positive. It follows that $x_{kc}=0$ and $c_{kc}>0$. Now consider an alternate assignment with $x_{rh}=1$, $x_{rc}=0$, $x_{kh}=0$, and $x_{kc}=1$. This new assignment is feasible since each row i still has one $x_{ij}=1$ and each column j still has one $x_{ij}=1$. In addition, the new assignment has the same objective function value as the original assignment. The total change in benefit, Z, is

$$Z=(c_{kc}-c_{kh})+(c_{rh}-c_{rc}) \tag{11}$$

which in expanded form is

$$[(O_k-O_c-T_{kc})-(O_k-O_h-T_{kh})]+[(O_r-O_h-T_{rh})-(O_r-O_c-T_{rc})] \tag{12}$$

Simplifying Eq (12) yields

$$(O_k-O_k)+(O_h-O_h)+(O_c-O_c)+(O_r-O_r)+(T_{rc}-T_{kc})+(T_{kh}-T_{rh}) \tag{13}$$

which reduces to

$$(T_{rc}-T_{kc})+(T_{kh}-T_{rh}) \tag{14}$$

Since the transportation cost (T_{ij}) is constant for every cell within a column, $T_{kc}=T_{rc}$ for column *c* and $T_{kh}=T_{rh}$ for column *h*. Therefore, the total change in benefit between the two assignments is zero. However, this new solution includes a decision variable, x_{rh}, with a negative benefit. As proven earlier, such a solution is not optimal. Hence, the original solution with a positive x_{ij} in the stairstep area cannot be optimal. Thus, there exists an optimal solution to the assignment problem with all nonzero decision variables in the *p*p* or do nothing regions of the tableau depicted in Figure 3. All decision variables in the solution with a nonnegative benefit then, must necessarily lie in the p*p matrix.

<u>p*p Solution</u>. For those decision variables within the p*p matrix, any feasible assignment within that matrix is optimal. Applying the Hungarian method to the p*p matrix will reveal the existence of alternate optimal solutions. Consider the largest nonnegative square matrix p*p of the (m+n)*(n+m) vehicle disposition assignment problem. The p rows correspond to the p highest valued surplus vehicles and the p columns to the p lowest valued fleet vehicles. The assignment tableau can be constructed as indicated in Table 9. As before, assume the surplus vehicles are arranged in

TABLE 9

INITIAL TABLEAU[*]

	F_1	F_2	F_3	F_4	...	F_p
S_1	O_1-OT_1	O_1-OT_2	O_1-OT_3	O_1-OT_4	...	O_1-OT_p
S_2	O_2-OT_1	O_2-OT_2	O_2-OT_3	O_2-OT_4	...	O_2-OT_p
S_3	O_3-OT_1	O_3-OT_2	O_3-OT_3	O_3-OT_4	...	O_3-OT_p
S_4	O_4-OT_1	O_4-OT_2	O_4-OT_3	O_4-OT_4	...	O_4-OT_p
⋮	⋮	⋮	⋮	⋮	⋮	⋮
S_p	O_p-OT_1	O_p-OT_2	O_p-OT_3	O_p-OT_4	...	O_p-OT_p

[*]NOTE: $OT_1, OT_2, \ldots, OT_p = O_j+T_{ij}$ for all i and j.

descending order, with the highest value surplus vehicle (for O_i) in the S_1 position. The reverse applies to the columns of fleet vehicles, where the F_1 column contains the vehicle with the lowest (O_i+T_{ij}) value and the sixth column the highest.

First Reduction. Subtract from the largest element in each row all other elements in that row. The sequential ordering of the rows and columns, as explained in the Matrix Characteristics section, means the largest row elements are located in the first column. Thus, for S_1F_2 in Table 9, the first reduction computation is $(O_1-OT_1)-(O_1-OT_2)$, which simplifies to $O_1-OT_1-O_1+OT_2$, or, $(-O_1)+OT_2$, which also can be written OT_2-O_1. The results of the first reduction computations are shown in Table 10.

Second Reduction. Subtract from the largest element in each column all elements within that column. Again, due to the ordering of the rows and columns, the largest column elements are located in the first row. Therefore, for the S_2F_2 cell from Table 10, the second reduction computation is $(OT_2-OT_1)-(OT_2-OT_1)$, or 0 (zero). Then draw the minimum number of horizontal and vertical lines through the tableau that will cover all zero cells. The results of the second reduction computations are indicated by Table 11. Since, at this point, all cost values equal zero, an easy solution is to draw a line through each row.

TABLE 10

FIRST REDUCTION COMPUTATIONS

	F_1	F_2	F_3	F_4	...	F_p
S_1	0	OT_2-OT_1	OT_3-OT_1	OT_4-OT_1	...	OT_p-OT_1
S_2	0	OT_2-OT_1	OT_3-OT_1	OT_4-OT_1	...	OT_p-OT_1
S_3	0	OT_2-OT_1	OT_3-OT_1	OT_4-OT_1	...	OT_p-OT_1
S_4	0	OT_2-OT_1	OT_3-OT_1	OT_4-OT_1	...	OT_p-OT_1
⋮	⋮	⋮	⋮	⋮	⋮	⋮
S_p	0	OT_2-OT_1	OT_3-OT_1	OT_4-OT_1	...	OT_p-OT_1

*NOTE: $OT_1, OT_2, \ldots, OT_p = O_j+T_{ij}$ for all i and j

TABLE 11

SECOND REDUCTION COMPUTATIONS

	F_1	F_2	F_3	F_4	...	F_p
S_1	0	0	0	0	...	0
S_2	0	0	0	0	...	0
S_3	0	0	0	0	...	0
S_4	0	0	0	0	...	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮
S_p	0	0	0	0	...	0

In this case, the number of lines drawn equals the number of rows, indicating the solution is optimal. The optimal assignment may include only the zero cells from the final reduction of the Hungarian method. In addition, the solution must include one assignment for each row and one for each column.

For this problem, any feasible assignment within the p*p matrix results in an optimal solution, as there are zeroes in every cell. Therefore, any systematic approach to designating the optimal solution is appropriate. An easily implemented technique is to select the cell values on a diagonal drawn down from the uppermost left corner through the tableau, as shown in Table 12.

TABLE 12

OPTIMAL SOLUTION ASSIGNMENTS

	F_1	F_2	F_3	F_4	...	F_p
S_1	0	0	0	0	...	0
S_2	0	0	0	0	...	0
S_3	0	0	0	0	...	0
S_4	0	0	0	0	...	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮
S_p	0	0	0	0	...	0

Conclusion. The diagonal solution to the Hungarian method problem is the identical assignment generated by the greedy algorithm. Both methods generate optimal solutions for the vehicle disposition problem. The greedy algorithm methodology does this by considering assignments (matched pairs) where the residual values of replacement, $O_i-(O_j+T_{ij})$, are positive. These assignments are equivalent to those in the largest p*p square of the assignment problem's m*n cost matrix. The greedy algorithm thus is an effective method for vehicle disposition.

Summary

Chapter III demonstrated the equivalence of the greedy algorithm and assignment problem approaches to the optimal surplus vehicle disposition problem by proving that the greedy algorithm generates optimal solutions. Both methodologies generate optimal solutions to the vehicle disposition problem. However, the greedy algorithm solution technique solves this feasible optimality with considerably less work than the traditional assignment problem approach, The greedy algorithm is, therefore, a practical method for optimally redistributing surplus vehicles. A demonstration and analysis of the greedy algorithm technique is the subject of Chapter IV.

IV. Demonstration and Analysis of Solution Technique

An advantage of the greedy algorithm described in Chapter III is its efficiency in solving larger problems that might otherwise tax the resources available to vehicle managers. The algorithm's efficiency stems from the fact that it obviates the need for maintaining and updating a large tableau for a series of iterations.

Use of the greedy algorithm is demonstrated in this chapter using data from Tactical Air Command (TAC). The data was derived from the command vehicle life expectancy listing dated 11 April 1991 (Hopkins, 1991).

Following the example is a discussion of issues affecting the use of the greedy algorithm for vehicle disposition. Such factors include the impact of changes in vehicle types, one-time repair allowance (OTRA) accuracy, decision buffers, and multiple shipment discounts on the optimal solution.

Solution Application

As mentioned in Chapter I, there are currently five Air Force bases scheduled for closure or curtailment through fiscal year (FY) 1994, three of which are TAC bases. TAC vehicle managers thus have an opportunity to increase the value of the remaining command fleet by using the greedy algorithm developed in Chapter III. Consider an application of the algorithm using Bergstrom AFB, TX as a closing base. Command vehicle managers must decide how to redistribute Bergstrom's 16 4x2 cargo pickup trucks (management code B204). The command is considering substitutions within a set of 532 fleet vehicles at 15 other TAC stateside bases.

An assumption has been made that the life expectancy listing represents each base's total authorized fleet of B204 pickup trucks. In other words, it is assumed there are no unfilled authorizations. Recall that all authorizations should be filled prior to determining which vehicles to substitute.

Step 1. Calculate the OTRA, O_i ($i=1,2,\ldots,16$), for each surplus vehicle. The OTRAs do not have to be manually calculated since they are included on the vehicle life expectancy listing.

Step 2. Order the list of surplus vehicles from highest to lowest by vehicle OTRA (O_i).

Step 3. Find (O_j+T_{ij}) ($i=1,2,\ldots,16;j=1,2,\ldots,532$) for each remaining fleet vehicle.

The 532 fleet vehicle OTRAs are also contained on the life expectancy listing. For this study, shipping cost estimates were obtained from the Headquarters Military Traffic Management Command's (MTMC) Directorate of Personal Property (MTMC PPQ), through the CONUS Freight Management System, and the MTMC-Eastern Area Inland Freight Division (Abrams, 1991; Tredway, 1991; Robertello, 1991; Taylor, 1991; Kiely, 1991). Rate quotes (rounded to the nearest ten dollars) were based on a vehicle weight of 4,600 pounds. The estimated transfer costs are listed in Table 13:

TABLE 13

ESTIMATED TRANSFER COSTS

	Base	Code	Shipping Cost
1.	Cannon AFB, NM	(CA)	$ 740.00
2.	Davis Monthan AFB, AZ	(DM)	1,440.00
3.	England AFB, LA	(EN)	580.00
4.	Holloman AFB, NM	(HO)	890.00
5.	Homestead AFB, FL	(HM)	1,570.00
6.	Langley AFB, VA	(LA)	1,750.00
7.	Luke AFB, AZ	(LU)	1,410.00
8.	MacDill AFB, FL	(MD)	1,290.00
9.	Moody AFB, GA	(MO)	1,470.00
10.	Mountain Home AFB, ID	(MH)	2,160.00
11.	Myrtle Beach AFB, SC	(MB)	1,440.00
12.	Nellis AFB, NV	(NE)	1,790.00
13.	Seymour Johnson AFB, NC	(SJ)	1,510.00
14.	Shaw AFB, SC	(SH)	1,320.00
15.	Tyndall AFB, FL	(TY)	930.00

Destination codes were developed for this example to allow the reader to better track the surplus vehicles through the procedure.

Step 4. Order the list of fleet vehicles from low to high, with the lowest value (O_j+T_{ij}) vehicle at the top of the list.

Step 5. Truncate the list of 532 fleet vehicles so the numbers of surplus and fleet vehicles are equivalent. The values in each of the two columns form sets of matched pairs, as indicated by Table 14:

TABLE 14

SURPLUS AND FLEET VEHICLE VALUES (STEP 5)

Surplus Vehicles	Fleet Vehicles	Code
$ 5,254.00	$ 1,723.00	(EN)
5,254.00	1,723.00	(EN)
5,254.00	1,723.00	(EN)
5,159.00	1,723.00	(EN)
5,085.00	1,723.00	(EN)
4,964.00	1,723.00	(EN)
4,870.00	1,723.00	(EN)
4,683.00	1,723.00	(EN)
4,601.00	1,723.00	(EN)
4,601.00	1,723.00	(EN)
4,601.00	1,723.00	(EN)
4,518.00	1,723.00	(EN)
1,186.00	1,723.00	(EN)
1,143.00	1,883.00	(CA)
1,143.00	1,883.00	(CA)
1,143.00	1,883.00	(CA)

Since 142 fleet vehicles had an OTRA of $1,143, which was the lowest OTRA value for the fleet, the shipping cost became the deciding factor identifying substitution candidates. Thirteen of those vehicles are assigned to England AFB, LA, which has the lowest shipping cost ($580). Cannon AFB, NM with the next lowest shipping cost of $740, is assigned 5 B204 pickups with OTRAs of $1,143.

Step 6. Index each list numerically, for order of replacement consideration, beginning at the top of the lists.

Step 7. For each pair, calculate the residual value of replacement, $O_i-(O_j+T_{ij})$. Steps 6 and 7 are illustrated by Table 15.

TABLE 15

RESIDUAL VALUES OF REPLACEMENT (STEPS 6 and 7)

Surplus Vehicle Replacement Consideration		Fleet Vehicle Replacement Consideration		Residual Value of Replacement	Code
1.	$5,254	1.	$1,723	$3,531	(EN)
2.	5,254	2.	1,723	3,531	(EN)
3.	5,254	3.	1,723	3,531	(EN)
4.	5,159	4.	1,723	3,436	(EN)
5.	5,085	5.	1,723	3,362	(EN)
6.	4,964	6.	1,723	3,241	(EN)
7.	4,870	7.	1,723	3,147	(EN)
8.	4,683	8.	1,723	2,960	(EN)
9.	4,601	9.	1,723	2,878	(EN)
10.	4,601	10.	1,723	2,878	(EN)
11.	4,601	11.	1,723	2,878	(EN)
12.	4,518	12.	1,723	2,795	(EN)
13.	1,186	13.	1,723	537	(EN)
14.	1,143	14.	1,883	(-740)	(CA)
15.	1,143	15.	1,883	(-740)	(CA)
16.	1,143	16.	1,883	(-740)	(CA)

Step 8. Designate the matched pairs with positive residual values for substitution (indicated by Table 16). Of the 16 surplus pickup trucks, it would be to TAC's advantage to substitute 13 of them for older vehicles at other bases. These 13 substitutions result in a net benefit of $38,705 for a vehicle type at one base being closed. In actuality, the benefit would be somewhat higher due to the probable multiple shipment discount that would apply. When considering all vehicle types at a single base to be closed, the potential benefit due to optimal surplus vehicle disposition promises to be much higher.

TABLE 16

OPTIMAL SURPLUS VEHICLE SUBSTITUTIONS

Bergstrom Vehicle O_i	Substitution Destination Base	O_j
5,254	England, LA	1,143
5,254	England	1,143
5,254	England	1,143
5,159	England	1,143
5,085	England	1,143
4,964	England	1,143
4,870	England	1,143
4,683	England	1,143
4,601	England	1,143
4,601	England	1,143
4,601	England	1,143
4,518	England	1,143
1,186	England	1,143
1,143	No substitution	
1,143	No substitution	
1,143	No substitution	

If a surplus vehicle designated for substitution is withdrawn from the set of surplus vehicles before the transaction for some reason, the need for a trade would be nullified. Consequently, the highest (O_j+T_{ij}) valued fleet vehicle would then be deleted from consideration, and the remaining fleet vehicles rematched with the surplus vehicles. The vehicles not designated for substitution would be identified to the vehicle item manager at Warner Robins for Air Force-wide visibility.

Problem Analysis

In the previous section, use of the greedy algorithm to solve a vehicle disposition problem was described. The algorithm can be used by any decision maker, at any level, when deciding how to redistribute surplus vehicles. Three requirements must be met:

1. The value used to measure the benefit of a transaction (c_{ij}) must be consistent for all vehicles, and reflect a single unit of measure, ie., dollars.

2. Surplus vehicles must generate from the same location if transportation costs are taken into account.

3. One resource type or group, ie., sedans, must be considered at a time.

In the following paragraphs, the impact of factor variations on the vehicle disposition problem are discussed.

Vehicle Types. The greedy algorithm works successfully for any vehicle type. As long as the value of a vehicle can be measured, this technique can be used. In addition, similar types of vehicles can be grouped together. For instance, a base might have a group of ten similar forklifts represented by five different management codes due to slight variations in design. If the major command (MAJCOM) sees no differences in the utilization and capability of each of the forklifts, the vehicles can be grouped together in the solution procedure.

OTRA Accuracy. The OTRA was used in this research to represent vehicle dollar value through use of a straightline depreciation approach based on age and mileage, kilometers, or hours accumulated. It does not, however, provide a way to detect problem vehicles, such as those with a high frequency of repair or history of major maintenance problems. Therefore, without taking mechanical history into account, a vehicle in poor condition might be substituted for a vehicle with a lesser OTRA, but in overall better condition.

Decision Buffer. The solution technique expounded in Chapter III supports substitution whenever the potential benefit, c_{ij}, of a transaction is positive. In reality, deciding when the potential benefit is sufficient to make a substitution is an operational decision. If the residual benefit is minimal, a decision to identify a surplus vehicle to WRALC for further disposition would be a reasonable course of action. Minimum cutoffs for the residual value thus can be established for substitutions to be considered beneficial.

Shipping Costs. Whether transfer costs should be considered is a fundamental issue. This research based the disposition decision on OTRAs and shipping costs in order to measure the net benefit of vehicle substitutions. A disposition policy based on OTRAs alone could result in a higher overall benefit to a vehicle fleet in terms of the OTRA, but cost more current dollars to achieve. Therefore, appropriate goals and objectives must be established before implementing a vehicle disposition policy.

<u>Multiple Shipment Discounts</u>. Chapter I defined estimated shipping costs as those costs associated with moving a single vehicle from an origin to destination. Single vehicle shipment costs represent the high end of the range of transportation costs (Taylor,1991). With literally thousands of vehicles and equipment items at a closing base, planners can stockpile surplus resources to move mass quantities at discount rates. In general, beyond a certain size, the larger the shipment, the lower the shipping cost.

For example, the freight rate to move one to six general purpose sedans from Granite City, IL to Charleston, SC amounts to approximately $258 per vehicle (Kiely, 1991). A shipment of seven sedans would decrease the price to $221 per vehicle; eight sedans, generally the maximum number of sedans a car carrier can hold, would result in another discount, reducing the cost to approximately $193 per sedan.

The changing mission requirements during a base closure make precise planning for multiple shipments difficult, especially since closing actions can take place over the course of several years. Consequently, vehicle availability for transfer would be difficult to predict with a high degree of accuracy. Clearly, as with decision buffers, the method of estimating shipping costs is an operational decision.

Summary

This chapter outlined an application of the greedy algorithm to a vehicle disposition problem that resulted from a base closure. When applicable, the technique is a more efficient methodology than standard assignment procedures. The applicability of the greedy algorithm depends on three requirements, which were outlined in this chapter. Like most analytical results, the solutions demonstrated in this chapter were not intended to make decisions, but to support a decision-making process. Sound operational judgement must be applied to ensure the input data and resulting output are properly used and integrated. Chapter V contains conclusions and recommendations for further research.

V. Conclusions and Recommendations

Chapter Overview

The significant decline in the fiscal year (FY) 1991 Department of Defense (DoD) budget was the beginning of a trend projected to continue into the 1990s for the DoD (Morrocco, 1990:26). As a result, a number of force structure reductions and base closures have been implemented. In light of associated budget constraints, base closures provide the Air Force with an opportunity to improve the value of its residual motor vehicle fleet through revised vehicle disposition policies. This research developed a methodology to accomplish this objective.

This chapter discusses conclusions and recommendations resulting from this research. The analysis contained in this study offers major commands (MAJCOMs) an optimal method of surplus vehicle disposition.

Conclusions

The three objectives guiding this research were:

1. Outline the current Air Force vehicle disposition policy in practice.

2. Propose a decision tool for use by a MAJCOM staff in the disposition of surplus vehicles.

3. Demonstrate the use of a structured approach to vehicle disposition.

As detailed in Chapter I, the current disposition policy is guided by Air Force Manual (AFM) 67-1. MAJCOMS fill open authorizations first, then replace eligible older vehicles. Remaining excesses are then identified to the Air Force vehicle manager, located at Warner Robins (WRALC), for Air Force-wide visibility.

Using an alternative approach to surplus vehicle disposition provides an opportunity to increase overall fleet value as measured by the one-time repair allowance (OTRA). As shown in Chapter III, surplus vehicle disposition may be modeled as an assignment problem. Optimal solutions to this problem may be obtained using the standard techniques described in the literature review. In addition, a very efficient greedy algorithm will generate an optimal vehicle disposition plan under special conditions regarding transportation.

Recommendations

Implementation. The greedy algorithm methodology can be adopted by the Air Force in a technical order or directive for use at both the MAJCOM staff and Warner Robins ALC vehicle manager levels. Although base closures provide an obvious opportunity for the Air Force to benefit from this method, the greedy algorithm can be used for any surplus vehicle disposition decision.

Automation. Computer code automating the steps of the process can be written and augmented into the current Air Force and MAJCOM vehicle databases. The program can include a decision factor which weighs the effects of potential multiple shipment discounts. The program could be modified according to the requirements of the user. For example, the vehicle manager at WRALC requires Air Force-wide visibility, whereas a MAJCOM only requires command-wide visibility.

Future Research. This methodology could be expanded to assess the impact of inter-command, rather than intra-command, visibility for the surplus vehicle disposition decision. This could yield significant positive benefits to the Air Force as a whole, particularly when large numbers of surplus vehicles are involved, such as during a base closure. Resulting benefits could include improvement in the overall vehicle fleet, as well as cost savings in shipping expenses.

Additional research could also verify the validity of the OTRA as a value measure, or suggest an alternative method for assessing the value of the surplus and fleet vehicles.

In addition, research could assess the feasibility of applying the greedy algorithm to assets other than motor vehicles resources. Use of such an optimization technique for base closure resource allocation could realize tremendous cost savings for the Air Force.

Finally, research could be done to find ways to include the consideration of multiyear shipping discounts into the surplus vehicle disposition problem.

Closure

This research has proven and demonstrated a method for optimal surplus vehicle disposition. This approach can improve the value of an Air Force MAJCOM vehicle fleet and thus defer near term replacement costs. Because the DoD budget is projected to decrease over the next several years, the ability to improve the value of a vehicle fleet provides the Air Force with a valuable opportunity.

Appendix: The Vehicle One-Time Repair Allowance

Air Force Technical Order (AFTO) 00-25-249, Maximum Repairs, Replacement Codes, and Priority Buy Program for USAF Vehicles, is the governing directive for the vehicle one-time repair allowance (OTRA). Throughout the life of a vehicle, the OTRA represents

> the maximum amount of money which can be spent for repair of a vehicle at any one time. This is based on two separate factors: miles/kilometers/ hours [M/K/H] accumulated and age. (AFTO 00-25-249, 1990:2-1)

In other words, the OTRA is used to aid in the decision whether or not a vehicle brought into a vehicle maintenance activity should be fixed (AFTO 00-25-249, 1990:4-1). The formulas used to calculate the OTRA are straight-line depreciation methods (Golden, 1986:30). There are two separate calculations -- age and utilization (M/K/H):

Age Computation=

$$\text{Repl Price} * \left(1-\frac{0.9 * \text{Age in months}}{\text{Life Expectancy in Months}}\right)$$

Utilization Computation=

$$\text{Repl Price} * \left(1-\frac{0.9 * \text{Utilization}^{*}}{\text{Utilization}^{*}\ \text{Life Expectancy}}\right)$$

[*] In Utilization Computations use miles, kilometers, or hours as indicated in the vehicle's MHUK Code (Reference T.O. 36A-1-1301). (AFTO 00-25-249, 1990:4-1)

The lower of the two calculations becomes a vehicle's OTRA. In any case, the OTRA "shall not be less than 10% of the standard price of the replacement vehicle" (AFTO 00-25-249, 1990:4-1).

If a vehicle OTRA is not available on the most recent vehicle master list, manual computations are necessary, using the One-Time Repair Worksheet (indicated by Figure 5) (AFTO 00-25-249, 1990:4-1).

ONE-TIME REPAIR WORKSHEET		SAMPLE Life Exp: 6 yrs and 100,000 miles Repl price : $60,000 Current age: 48 months Current mileage: 40,000
STEP	COMPUTATION	
1A	Divide age in months by life expectancy in months.	48/72=0.6667
1B	Divide miles(M), hours(H), or kilometers(K) by life expectancy in M, H, or K. Data must be compatible. Do not divide H by M, e.g.	40000M/100000M=0.4000
1C	Enter the larger of step 1A or step 1B.	0.6667
2	Multiply step 1C by 0.9.	0.6667*0.9=0.6000
3	Subtract step 2 from 1.0.	1.0-0.6000=0.4000
4	If answer in step 3 is less than 0.10, change it to 0.10 and enter answer in step 4. Otherwise just copy step 3 answer in step 4.	0.4000
5	Multiply step 4 by the I&S master NSN price. (This gives you the one-time repair.)	0.4000*$60000=$24000 OTRA=$24,000

Figure 5. One-Time Repair Allowance Computation Worksheet (adapted from AFTO 00-25-249, 1990:4-2)

The repair cost estimate is then compared with the OTRA to make the repair decision. In general, if an estimate does not exceed any of the vehicle life expectancy criteria

(OTRA, age, utilization), repairs can be made (AFTO 00-25-249, 1990:4-1). Otherwise, repair is considered uneconomical. In this case there are two alternative actions that may be taken. First, repair approval can be obtained from the base level vehicle maintenance officer/superintendent for minimum essential repairs, or from the Chief of Transportation (or Transportation Squadron Commander) for major repairs (AFTO 00-24-259, 1990:4-3). Second, if the vehicle is judged excess or nonessential to mission requirements, the vehicle should be reported for disposition (AFTO 00-25-249, 1990:4-1).

Bibliography

Abrams, A1C Veronica S., Shipment Planner. Telephone interviews. Traffic Management Office. Wright-Patterson AFB OH, July through August 1991.

Bird, Julie. "AF Closings Reflect B-52, A-10 Cutbacks," Air Force Times, 51: 4 (22 April 1991).

Brown, Kenneth S. and Jack B. ReVelle. Quantitative Methods for Managerial Decisions. Wesley, London: Addison Wesley, 1978.

Cook, Thomas and Robert A. Russell. Introduction to Management Science (Fourth Edition). Englewood Cliffs NJ: Prentice Hall, 1989.

Department of the Air Force. Vehicle Operations Acquisition, Management, and Use of M or Vehicles. AFM 77-310, Volume I. Washington DC: HQ USAF, 11 January 1991.

Department of the Air Force. "Approved and Pending Base Realignments and Closures." Memorandum. Washington DC: HQ USAF, 5 December 1990a.

Department of the Air Force. Base Closures. AFR 67-1, Volume II, Part Two. Washington DC: HQ USAF, 3 December 1990b.

Department of the Air Force. Distribution/Redistribution. AFR 67-1, Volume IV, Part One, Chapter 17. Washington DC: HQ USAF, 3 December 1990c.

Department of the Air Force. Maximum Repairs, Replacement Codes, and Priority Buy Program for USAF Vehicles. AFTO 00-25-249. Washington DC: HQ USAF, 26 December, 1985, (C1) 5 Jan 90, (C2) 30 May 90.

Golden, Capt John H. An Application of Linear Regression to the Allocation of General Purpose Vehicles. MS thesis, AFIT/GLM/LSM/86S-26. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1986 (AD-A174566).

Hargreaves, John. "Resource Allocation: Optimisation for Tomorrow's Demand," International Journal of Physical Distribution & Materials Management (UK), 19: 18-25 (May 1989).

HQ 509th Bombardment Wing (BMW) (SAC), USAF. 509 MMW Inactivation and Pease AFB Closure Plan. Pease AFB NH: 509 CSG/CCEC, 31 July 1989.

Heinze, David. Management Science Introductory Concepts and Applications. Dallas: South-Western, 1978.

Hill, Henry, Vehicle Manager, Vehicle Management Directorate. Telephone interview. WR-ALC/LV, Warner Robins AFB GA, 28 June 1991.

Holley, CMSgt Daniel E., Vehicle System Coordinating Officer. Personal and telephone interviews. HQ AFLC/MMCO, Wright-Patterson AFB OH, December 1990 through July 1991.

Hopkins, MSgt Mike, Vehicle Manager, Directorate of Transportation. Telephone interviews. HQ TAC/LGTV, Langley AFB VA, March through June 1991.

Jung, Phil, Lt Col, HQ USAF/LEXP. Comments in recorded minutes of 22nd Annual Air Force Worldwide Transportation Conference. Homestead AFB FL, 9-13 April 1990.

Kiely, John, Assistant Chief, Freight Traffic Management. Telephone interviews. MTEA-INF, Bayonne NJ, August 1991.

Mason, L.G. and A. Girard. "Multilocation Facility Modernization: Models and Heuristics," Operations Research, 38: 412-425 (May-June 1990).

Morrocco, John D. "Pentagon Begins Drawdown but Offers No New Strategy (Part 1)," Aviation Week & Space Technology, 132: 26-27 (February 1990).

Pinney, William E. and Donald B. McWilliams. Management Science. New York: Harper and Row, 1987.

Robertello, Maj Catherine, Directorate of Personal Property. Telephone interview. HQ MTMC PPQ, Falls Church VA, 16 August 1991.

Taylor, James, Chief, Freight Traffic Management. Telephone interviews. MTEA-INF, Bayonne NJ, August 1991.

3760 Technical Training Group (TTG) (ATC). "Vehicle Management and Maintenance Management." No. SG J 30AR6011 000-III-1&2. Transportation Staff Officer Course, Sheppard AFB TX, August 1988.

Tredway, Estelle B., Director of Marketing and Membership. Telephone interviews. National Moving and Storage Association, Springfield VA, July through August 1991.

Trueman, Richard E. An Introduction to Quantitative Methods for Decision Making. New York: Holt, Rinehardt & Winston, 1977.

Tucker, Becky, Shipment Planner. Personal interview. Traffic Management Office. Wright-Patterson AFB OH, 21 May 1991.

Vita

Captain Tredway was born 21 January 1962 in Honolulu, HI. She graduated from high school in Fairfax, VA in 1980 and attended the University of Texas at Austin, receiving a Bachelor of Business Administration in Management in May 1984. In April 1986, Captain Tredway earned her commission through OTS. Upon completion of the Transportation Officer Course, she was assigned Vehicle Operations Officer, 60th Transportation Squadron, Travis AFB, CA. There she managed a fleet of 900 vehicles and 80 civilian and military personnel. Captain Tredway was awarded a Master of Business Administration degree in Management from Golden Gate University in March 1988. She also completed Squadron Officer School by correspondence in 1988. In November 1988, Captain Tredway was reassigned to the 1605th Transportation Squadron, Lajes Field, Azores, as Vehicle Operations Officer, managing 56 Portuguese national civilian and American military personnel, and an average fleet of 460 vehicles. Captain Tredway was reassigned as the squadron's first Combat Readiness and Resources Officer in September 1990, where she was responsible for plans and programs, until entering the School of Systems and Logistics, Air Force Institute of Technology, in May 1990.

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13. ABSTRACT (*Maximum 200 words*) This study developed a disposition method to enable major commands to increase the value of their vehicle fleets by optimally replacing less valuable fleet vehicles with more valuable surplus vehicles. The value of an optimal vehicle disposition method is especially significant in light of the decline in the U.S. Department of Defense (DoD) budget and base closures scheduled through fiscal year 1994. The Air Force currently spends approximately $240 million per year for vehicle replacement to maintain its motor vehicle fleet. It is advantageous, therefore, to consider replacing older vehicles in the fleet with newer surplus vehicles made available through the closures. Using a greedy algorithm approach to vehicle disposition, this research demonstrated a potential savings of almost $39,000 for the disposition of only 13 pickup trucks at a single base considered for closure. This method is more efficient than standard linear programming assignment procedures, yet is flexible enough to use in conjunction with sound judgement to support all surplus vehicle disposition decisions.

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